HEAVEN & EARTH

Our Universe

Answers IN GENESIS™

GOD'S DESIGN®

4th Edition

Debbie & Richard Lawrence

God's Design® for Heaven & Earth is a complete earth science curriculum for grades 3–8. The books in this series are designed for use in the Christian homeschool and Christian school, and provide easy-to-use lessons that will encourage children to see God's hand in everything around them.

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Welcome to GOD'S DESIGN®

HEAVEN & EARTH

You are about to start an exciting series of lessons on Earth science. *God's Design® for Heaven and Earth* consists of three books: *Our Universe*, *Our Planet Earth*, and *Our Weather and Water*. Each of these books will give you insight into how God designed and created our world and the universe in which we live.

No matter what grade you are in, third through eighth grade, you can use this book.

3rd–5th grade

Read the lesson.

- Do the activity in the light blue box (worksheets will be provided by your teacher).
- Test your knowledge by answering the **What did we learn?** questions.
- Assess your understanding by answering the **Taking it further** questions.

Be sure to read the special features and do the final project.

There are also unit quizzes and a final test to take.

6th–8th grade

Read the lesson.

- Do the activity in the light blue box (worksheets will be provided by your teacher).
- Test your knowledge by answering the **What did we learn?** questions.
- Assess your understanding by answering the **Taking it further** questions.
- Do the Challenge section in the light green box. This part of the lesson will challenge you to do more advanced activities and learn additional interesting information.

Be sure to read the special features and do the final project.

There are also unit quizzes and a final test to take.

When you truly understand how God has designed everything in our universe to work together, then you will enjoy the world around you even more. So let's get started!

UNIT 1

Space Models

◊ Identify models used to understand the universe.

◊ Describe how models are used in science.

◊ Describe how lenses and mirrors are used to explore space.

1

Introduction to Astronomy

Study of space

What is astronomy, and why should we study it?

Words to know:

astronomy   big bang theory

Psalm 19:1 says, "The heavens declare the glory of God." Since the Bible is always true, we should want to study and understand the heavens so that we can better understand God's glory. The study of the heavens is called astronomy. **Astronomy** is the study of the planets, moons, stars, and other things found outside of the earth. In this book you will learn about these things and many other things in the universe as well.

Have you ever looked at the stars and wondered what they were or how they got where they are? Have you ever observed the movement of the sun through the sky and wondered how it moves like it does? Then you are asking some of the same questions that astronomers have asked for hundreds of years. Scientists cannot prove where the universe came from. A popular theory among some scientists is the **big bang theory**—the idea that the universe suddenly came into existence nearly 14 billion years ago and has been expanding ever since. However, in Genesis 1:14–19, the Bible says that God created the sun, moon, and stars on the fourth day of creation, so we know how the sun, moon, and stars got where they are—God created them. Many of the other questions have been answered by scientists as they have observed the universe and studied how things move and work together. In this book, you will learn many of the things that astronomers and other scientists have discovered as well as many things that the Bible has to say about the universe that we live in.

God's purpose

Complete the "God's Purpose for the Universe" worksheet.

What did we learn?

- What is astronomy?
- Why should we want to study astronomy?

Taking it further

- What is one thing you really want to learn during this study?
- Write your question or questions on a piece of paper and save it to make sure you find the answers by the end of the book.

Knowledge of the Stars

The word *astronomy* comes from two Greek words, which mean "star arranging." It means to arrange or systematize our knowledge of the stars. What knowledge do you have of the stars? Test your knowledge of the stars by completing the "Knowledge of the Stars" worksheet. Try to find the answers to the questions you are not sure of in any books you may have on astronomy or on the internet.

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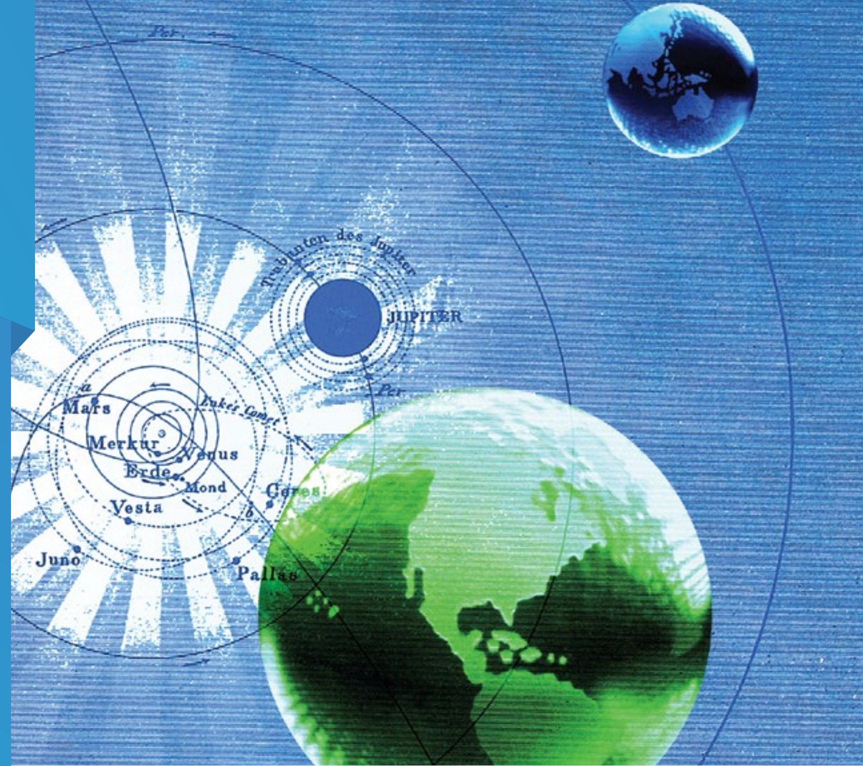


Space Models

What's really out there?

How do we know what our solar system looks like?

Words to know:

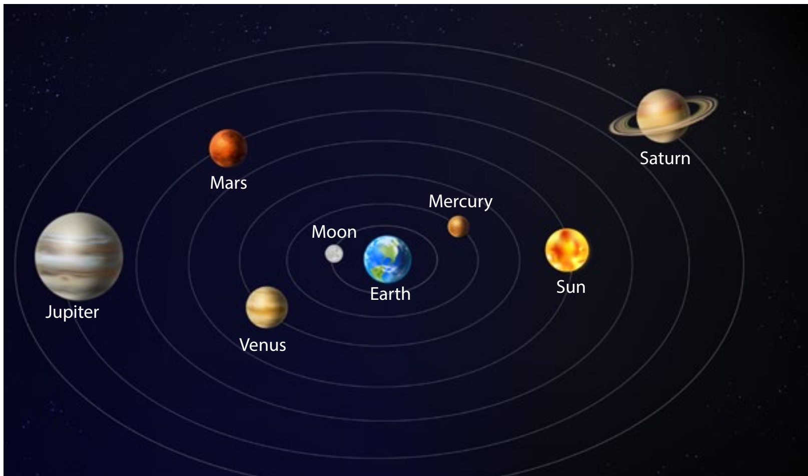
geocentric model	law of gravitation
heliocentric model	gravity

Have you ever played with a model car or a model airplane? Have you ever built a model train or seen a model space ship? A model is a smaller version of the real thing. It allows you to see and touch something that is too big to actually hold or play with. Space is much too big to hold or even to see completely. So man has invented models to help us understand what the universe looks like and how it works. A model of space can be very useful. These models are often drawings and not three-dimensional toys, although we sometimes see three-dimensional models of our solar system. But how did people figure out what the universe and our solar system looked like and how they work?

Geocentric model

One ancient model of the solar system was based on what is called the **geocentric model**, which means that the earth was believed to be the center of the universe. This model was developed based on several observations. First, the earth appears to be stationary while the sun, moon, and stars seem to move around it. The sun rises in the east and sets in the west. The moon also rises in the east and sets in the west. And the stars move across the sky. Therefore, it made sense to early observers that the earth was in the center and everything else moved around it.

Careful observation also revealed that the sun, moon and the five visible planets appeared to move among the stars. So the early model showed the earth in the center with the sun, moon, and planets each in its own sphere spinning around the earth. The stars



Geocentric model

were believed to be in the outermost sphere. The spheres were thought to be crystal or some other transparent material that allowed the people on Earth to view the objects in them.

This model was developed over several hundred years. A Greek scientist named Ptolemy did much of the work, and the geocentric model is sometimes referred to as the Ptolemaic model. However, Ptolemy and others made observations that did not fit well within the theory. Sometimes planets seemed brighter and nearer, and at other times they seemed dimmer and farther away. Also, the planets sometimes appeared to slow down and even move backward with respect to the stars. To accommodate these observations, Ptolemy shifted the earth so it was not in the exact center of the model. He then said that the planets moved in small circles within their spheres to account for the apparent backward motion. This model did not fully explain all of the inconsistencies that were observed, but it was the best model available and, for centuries, was accepted as the way the universe was.

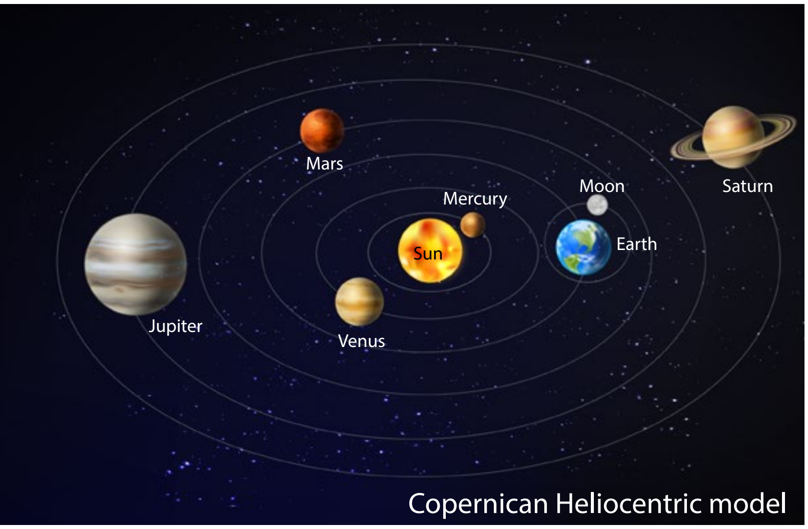
Heliocentric model

Then, during the Renaissance, there was a renewed interest in art, science, and learning. Many scientists began to make careful observations of the heavenly bodies, and new ideas began to emerge. A Polish astronomer named Nicolaus Copernicus developed the idea that the sun, not the earth, was the center of the solar system. This has been called the Copernican or **heliocentric model**. His model was able to explain many of the problems that had been observed in the geocentric model. Earth moving around the sun just like the other planets would explain why sometimes the planets appeared to move backward. The earth would catch up with slower moving planets, causing them to seem to slow down. Then after passing them, the planets' forward motion could be seen again.

Other scientists that followed Copernicus built on his foundation and were able to explain even more of what was observed. Johannes Kepler was a mathematician who very carefully plotted the movements of the planets and proved that the planets move in elliptical (or stretched) orbits instead of circular orbits, which helped explain why planets sometimes appeared closer than at other times.

The same year that Kepler published his work, another scientist, Galileo Galilei, designed and built his first telescope. He was the first one to study the heavens with a telescope. This invention allowed for much more precise measurements of the heavenly bodies and even better understanding of the workings of the planets and stars.

Finally, in the late 1600s Sir Isaac Newton used his knowledge to explain how all of these heavenly bodies were able to move the way they do. He devised his law of gravitation, which explained how gravity helps to hold all of the planets in their orbits around the sun. Throughout the years many improvements have been made to these theories, but the basic ideas of the Copernican model have remained the same. Today we know that the universe



Copernican Heliocentric model


The motion of stars across the sky can be seen with a long exposure photograph.

is much, much larger than was believed in the 17th century, but the heliocentric model explains what we observe in our solar system.

Law of gravitation

Newton's **law of gravitation** states that everything exerts a pull on everything else. The more massive something is, the stronger its gravitational pull, and the closer something is to an object, the stronger its gravitational pull. Because the earth is very large and very close to us, it has a strong gravitational pull on everything on the surface of the earth.

The earth and moon exert a gravitational pull on each other. Because the earth's mass is much larger than the moon, the moon orbits the earth. Similarly, the sun and the earth exert a gravitational pull on each other. But because the sun is much more massive than the earth, the earth revolves around the sun.

Gravitational pull

Purpose: To demonstrate that the speed at which an object falls due to the pull of gravity does not depend on the weight of the object.

Materials: ping-pong ball, golf ball, piece of paper, book

Procedure:

1. Hold a ping-pong ball and a golf ball. Which one is lighter?
2. Hold them both at the same height and release them at the same time. Which one hit the ground first?
3. Hold a book and a small, flat sheet of paper out at the same height and release them at the same time. Which one hit the floor first? Why?
4. Place the paper on top of the book and drop them at the same time. Did the paper float down slowly this time?
5. Finally, crumple the piece of paper into a small ball. Now, hold the book and the paper ball at the same height and drop them at the same time. Did they land at the same time?


Leaning Tower of Pisa

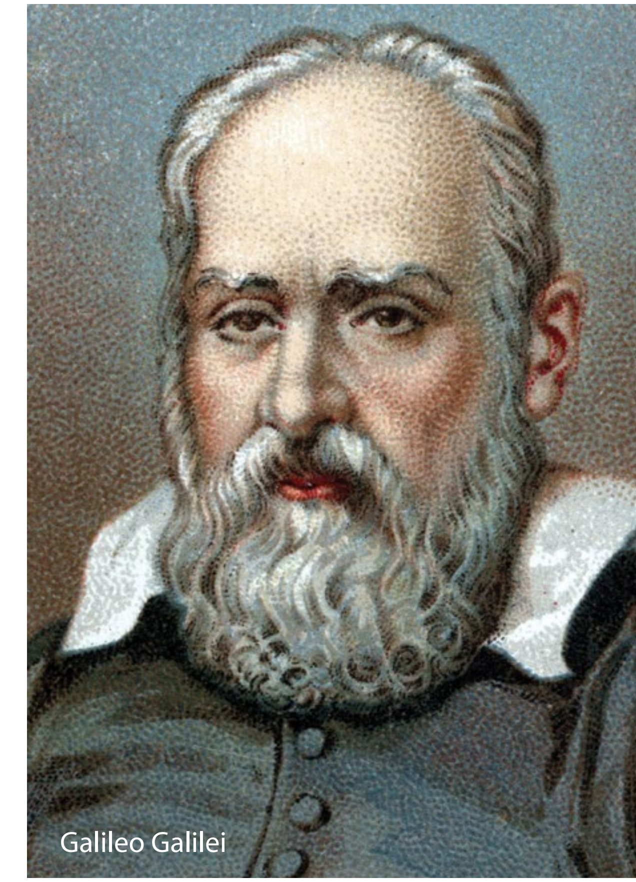
Questions:

- Why did the book hit the ground before the sheet of paper?
- Why did the sheet of paper on top of the book stay with the book?
- Why did the crumpled piece of paper hit the ground at the same time as the book?

Conclusion:

People used to think that heavier items fell faster than lighter items—that seems logical, right? Our activity showed this to be false. The ping-pong ball and golf ball should have hit the ground at about the same time even though the golf ball is much heavier. You may think that the book hit the ground before the paper because it is heavier. But you have now shown that is not the reason the paper floated slowly down. The sheet of paper floated down because of air resistance, not the pull of gravity. The paper ball did not have as much resistance to the air as the flat sheet of paper did, so it fell at about the same rate as the book. Understanding gravity is important because the force of gravity pulls objects down, holds our atmosphere in place, and keeps planets in orbit around the sun.


Johannes Kepler


Galileo Galilei

Although Newton is credited with proving the law of **gravity**, he was not the first to recognize that the earth pulls down on objects, nor was he the first to do experiments to test the pull of the earth. According to popular legend, Galileo did many experiments by climbing to the top of the Tower of Pisa and dropping various objects over the side, but this legend is probably not true. Nonetheless, Galileo did perform some ingenious experiments while at Pisa. He experimented with falling objects, projectiles, inclined planes, and pendulums. Galileo discovered that the speed at which an object falls is the same regardless of the weight of the object.

What did we learn?

- What are the two major models that have been used to describe the arrangement of the solar system?
- What was the main idea of the geocentric model?
- What is the main idea of the heliocentric model?
- What force holds all of the planets in orbit around the sun?

Taking it further

- Which exerts the most gravitational pull, the earth or the sun?
- If the sun has a stronger gravitational pull, then why aren't objects pulled off of the earth toward the sun?

Research the scientists

Choose one of the following scientists to research.

- Hipparchus
- Ptolemy
- Tycho Brahe
- Johannes Kepler
- Galileo
- Sir Isaac Newton
- Nicolaus Copernicus

Try to find the answers to the following questions:

1. When did he live?
2. What was the accepted space model at that time?
3. What problems were observed with the accepted model?
4. What contributions did he make to the space model that he believed in?
5. What arguments did he have to answer and how did he answer them in support of the model he believed in?

Write up your answers and present them to others so they can have a better understanding of how we developed the model of space we have today.

Nicolaus Copernicus

1473–1543

Nicolaus Copernicus is known as the person who changed the way the world views the universe. However he was not always known as "Nicolaus Copernicus," which was the Latin form of his name. His birth name was Mikolaj Kopernik or Nicolaus Koppernigk.

Nicolaus was born in 1473, in Poland. His father traded in copper and was a magistrate. When Nicolaus was about 10 years old, his father died and his uncle Lucas Waczenrode took him and his family in. His uncle was a canon, or clergyman, at the time.

When Nicolaus was about 15, his uncle sent him to a Cathedral school for three years. After that, he and his brother went on to the University of Krakow. Nicolaus studied Latin, mathematics, astronomy, geography, and philosophy. He later said that the university was a big factor in everything he went on to do. It was there that he started using his Latin name.

After four years of study, he returned home without a degree, a common practice at the time. His uncle wanted him to have a career in the church. To give him the needed background, he sent Nicolaus to the University of Bologna (Italy) to get a degree in canon law. While there, through the influence of his uncle, he was appointed canon at Frauenburg, which provided him with a nice income.

Shortly after this, he asked his uncle if he could return to school to complete his law degree and to study medicine. His uncle probably would not have let him go if he were not going to study medicine. The leader of the Cathedral Chapter thought it worthwhile and gave him the necessary funds. The study of medicine may have been an excuse to study his real passion, astronomy. At this time astronomy was little more than astrology and, therefore, used in medicine. It is not known if Nicolaus ever completed his medical training, but upon returning home, he worked for about five years as his uncle's doctor.

Although he worked as a doctor, Copernicus continued to study astronomy. At the time, most people believed that Earth was the center of the universe and all heavenly bodies orbited around it. However, Copernicus came to a different conclusion based on his studies of the heavens. And in 1514 he distributed a handwritten book on astronomy, without an author's name in it. The book made the following points:

- The earth's center is not the center of the universe; the center of the universe is near the sun.
- The distance from the earth to the sun is imperceptible compared with the distance from the earth to the stars.
- The rotation of the earth accounts for the apparent daily rotation of the stars.
- The apparent annual cycle of movements of the sun is caused by the earth revolving around it.
- The apparent retrograde motion of the planets is caused by the motion of the earth from which one observes the planets.

These ideas were revolutionary and not commonly accepted, which is why Copernicus published his book without his name in it. This little book was a precursor to his major work, which was completed at the end of his life. Copernicus did not spend his whole life studying and writing, however. In 1516, Copernicus was given the administrative duties of the districts of Allenstein for four years. In 1519, when war broke out between Poland and the Teutonic Knights, he was in charge of defending his area. In 1521 he was able to successfully lead the defense of Allenstein Castle, and an uneasy peace was restored. He was next appointed Commissar of Ermland and given the job of rebuilding the area after the war. Around 1522, he returned to Frauenburg and finally got the peaceful life he was looking for.

Even during the war, Copernicus continued his observations of the heavens. And after returning to Frauenburg, he began to work continuously on his book. Copernicus's theory of the solar system may have remained unknown, however, if not for a young Protestant named Rheticus who came to visit Copernicus in 1539. It was an unusual thing for a Protestant to visit a Catholic stronghold at this time, but Rheticus lived with Copernicus for about two years and helped him get his book published.

Rheticus took the manuscript to a printer named Johann Petreius in Nürnberg. He was unable to stay around and watch over the printing of the book, so he asked a friend named Andreas Osiander, a Lutheran theologian, to oversee it. Andreas Osiander removed the introduction letter originally written by Copernicus, and inserted his own. This substitute letter said that the book was to be used as a simpler way to calculate the positions of the heavenly bodies and not to be taken as truth. Copernicus received his first copy of the book on the day he died, so the switch was not discovered for 50 years.

When Osiander's switch was discovered, some people were appalled; others felt it was the only reason the work was not immediately condemned by the Catholic Church. Regardless of the reasons for the switch, the publication of the book changed the way man looks at the universe. Copernicus's work went on to inspire Galileo and Newton and generations of scientists to follow.

3

The Earth's Movement

Rotating and revolving

How does the earth move, and how does that affect us?

Words to know:

rotation
revolution
solstice
equinox

Challenge words:

Foucault pendulum

Various models of the universe were based upon observations about how the earth and other heavenly bodies move. When the geocentric model was the accepted model, scientists observed that the sun rose in the east and set in the west and that a day was 24 hours long. They also observed that the stars appeared to move through the sky. This led them to believe that these objects moved around the earth. However, these observations can be accounted for in the heliocentric model as well by showing how the earth moves with respect to the sun and the stars.

The earth's movements

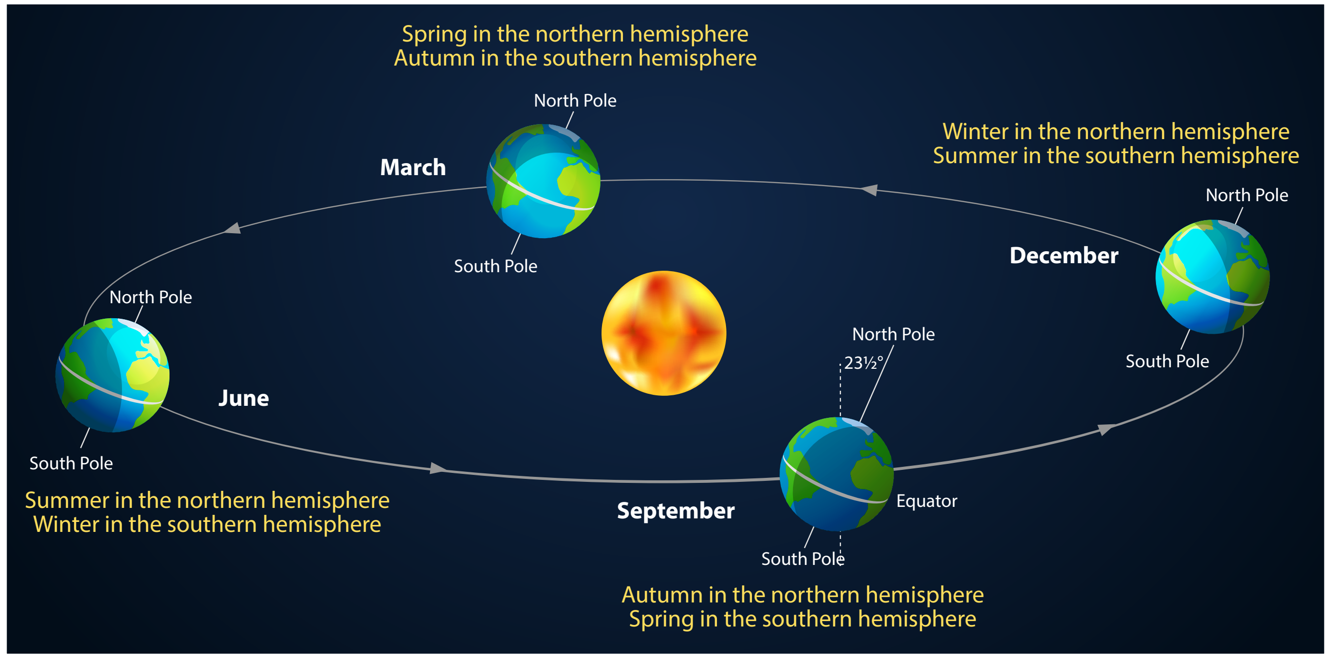
Once the heliocentric model was accepted, scientists began to make very careful measurements of how the earth moves. The earth moves in two different ways. First, it rotates on its axis, an imaginary line going from the North Pole to the South Pole through the center of the earth. Second, the earth revolves around the sun.

Rotation

The **rotation** of the earth on its axis explains how we experience the rising and setting of the sun and the relative movement of the stars. It also explains other observations that could not be easily explained by a stationary Earth.

The earth bulges slightly around the equator. The diameter of the earth measured at the poles is approximately 7,900 miles (12,700 km), but the diameter at the equator is about 7,927 miles (12,756 km). This difference is caused by rotation. Accurate measurements of Jupiter and Saturn show that they bulge even more around the center because they are more massive and spin faster than Earth. On the other hand, Mercury and Venus bulge less around the center because they spin at a slower rate than the earth.

Another indication of a spinning planet is the movement of air and water masses on Earth. The rotation of the earth causes something called the Coriolis effect. Hot air near the equator rises and colder air from the poles moves in to take its place. Without the rotation of the earth, this air would



move in vertical lines from the equator to the poles and back. However, what is observed is a diagonal airflow with respect to the earth's axis. This is caused because the air near the equator moves faster than the air near the poles due to the rotation of the earth. The Coriolis effect due to the rotation of the earth also causes cyclones to spin counter-clockwise in the northern hemisphere and clockwise in the southern hemisphere.

Revolution

The second way the earth moves is by revolving around the sun. The path the earth takes in its **revolution** around the sun is called its orbit. When scientists accepted the geocentric model, they accounted for changing seasons by saying that the sun moved differently around the earth at different times of the year. But seasons are better explained by the earth orbiting the sun and the tilt of the earth's axis. The earth is not completely vertical with respect to the sun. The earth is tilted 23½ degrees from vertical. When the northern hemisphere is tilted toward the sun, the sun's rays are more direct, causing warmer temperatures in that hemisphere during the summer. When the northern hemisphere is tilted away from the sun, the sun's rays hit at a lower angle, causing less heating and therefore lower temperatures in the winter. The seasons are reversed in the southern hemisphere.

The four parts of Earth's orbit

The earth's orbit is divided into four parts. The summer **solstice**, the first day of summer in the northern hemisphere, occurs on June 21st, when the sun's rays directly hit the Tropic of Cancer, which is an imaginary line around the earth at 23½ degrees north of the equator. The earth reaches the halfway point in its orbit on December 21st, the first day of winter in the northern hemisphere, or the winter solstice. This is when the sun's rays directly hit the Tropic of Capricorn at 23½ degrees south of the equator. Halfway between these points is the spring **equinox**, the first day of spring, which occurs on March 21st, and the autumnal equinox, the first day of autumn, which occurs on Sept. 22nd.

Other observations also point to a moving Earth. First, with powerful telescopes, scientists have observed something called parallax of the stars. This is where stars that are closer seem to shift their positions with respect to stars that are farther away as the earth moves through space. To understand parallax, think of standing behind a chair and looking at a picture across the room. From where you stand, the chair would be directly in front of the picture. But if you move sideways a few feet and look at the same picture, the chair would now appear to be to the side of the picture. When astronomers look at stars that are far away, they can see closer stars at the same time. If they look at the same stars several days later, the stars appear to be in different positions with respect to each other because the earth has moved. In fact, a lack of observed parallax was one argument against Copernicus when he first suggested the heliocentric model. He argued that there was a parallax but that they could not observe it because the distances to the stars were too great. He has been proven correct with the invention of powerful telescopes that can now measure these apparent movements.

Finally, it has been observed that more meteors and brighter meteors are observed after midnight than before midnight. This occurs because as the earth rotates on its axis, the area on the earth where it is between midnight and sunrise is on the forward part of the orbit. It is moving toward oncoming debris in space and more collisions will be observed during this time. These observations, as well as many others, support the heliocentric model and demonstrate the rotation and revolution of the earth.

What did we learn?

- What are the two different types of motion that the earth experiences?
- What observations can we make that are the result of the rotation of the earth on its axis?
- What observations can we make that are the result of the revolution of the earth around the sun?
- What is a solstice?
- What is an equinox?

Taking it further

- What are the advantages of the earth being tilted on its axis as it revolves around the sun?
- One argument against Copernicus's theory was that if the earth were moving, flying birds would be left behind. Why don't the birds get left behind as the earth moves through space?

Demonstrating movement

Activity 1—Purpose: To demonstrate how a rotating Earth gives hours of daylight and darkness

Materials: masking tape, volleyball or basketball, flashlight

Procedure:

1. Place a small piece of masking tape on a basketball or volleyball then hold the ball out in front of you.
2. Have another person hold a flashlight representing the sun and shine it on the ball. Slowly rotate the ball.
3. Observe when the light is shining on the piece of tape and when the tape is in the shadow or darkness. This shows how we experience day and night.

Activity 2—Purpose: To demonstrate the observed parallax of stars

Materials: None

Procedure:

1. Hold your arm straight out in front of you with one finger pointing up.
2. Using only your right eye, look at a distant object, noting where your finger is with respect to the object.
3. Close your right eye and look at the object with your left eye. Note how your finger appears to shift with respect to the distant object.
4. Repeat several times, alternating which eye is open.

Conclusion:

The different locations of your eyes represent the different locations of the earth with respect to the stars. It is easy to see the finger appear to move because the finger and the object are both relatively close to you. However, this effect is harder to see with the stars because they are so far away from the earth. Powerful telescopes are needed to see the stars clearly. With modern telescopes astronomers have observed parallax among stars, which confirms that the earth is moving through space.

Foucault pendulum

Even after scientists concluded that the earth must rotate on its axis, it was very difficult to demonstrate this movement. One idea was to drop a rock down a very deep shaft and see if it moved sideways compared to the shaft. This did not work because the depth of the shaft was very small compared to the radius of the earth, so the sideways movement was too small to measure. A similar experiment was to fire a cannon ball north to south and measure its movement east to west. Again however, the movement was too small to measure.

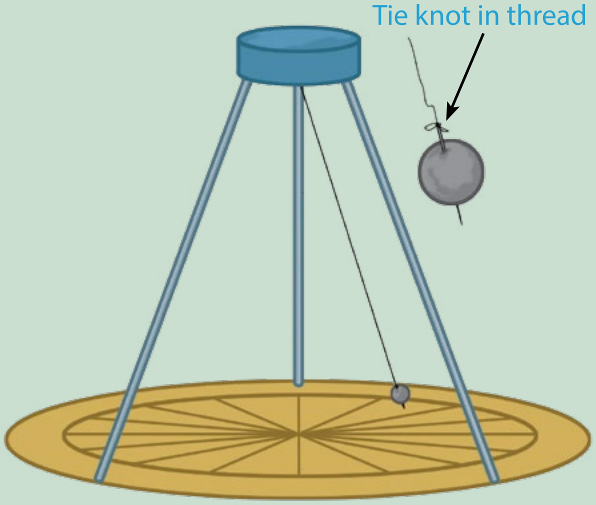
Eventually however, a French scientist named Leon Foucault devised a way to demonstrate the rotation of the earth. Foucault used a very long pendulum which would swing slowly. He placed marks in a circle on the floor below the pendulum. This allowed an observer to watch the path of the swinging pendulum. Over time, the pendulum appeared to change its path, but what was actually happening was the earth was rotating under the pendulum, thus moving the marks in the circle. This device is called a **Foucault pendulum**.

Purpose: To demonstrate the movement of the earth with your own Foucault pendulum

Materials: copy of clock pattern, needle, thread, tape, modeling clay, tripod, swivel chair, stool, or turntable

Procedure:

1. Tape a copy of the clock pattern to the top of a swiveling chair, stool, or other turntable.
2. Place a tripod on top of the chair and center the tripod over the circle.
3. Cut a length of sewing thread long enough to reach from the center of the tripod to the clock circle.
4. Thread one end of the string through a needle and tie a knot in the thread to prevent the needle from slipping off.
5. Push the needle through a ½-inch ball of modeling clay so that a small amount of the needle sticks through the end of the clay.



6. Tape the other end of the thread to the center of the tripod so that the needle swings freely just above the circle.
7. Start the thread gently swinging across the circle from 12 to 24.
8. Smoothly turn the chair ¼ of a turn to the right. Observe the numbers that the needle is now swinging across.
9. Turn the chair ¼ of a turn more and observe the numbers over which the needle is swinging.
10. Repeat until a complete turn has been made.

Questions:

- What forces are affecting the pendulum?
- Why does the pendulum eventually stop moving?
- How does a Foucault pendulum keep moving for hours or days at a time without stopping?

Conclusion:

Although the tripod and circle are moving with the chair, the swinging of the thread is mostly unaffected by its turning. Full-size Foucault pendulums can be seen in many museums and they demonstrate the rotation of the earth in much the same way as your smaller model.

Fun Fact

In 1852, Leon Foucault also invented the gyroscope, a special kind of top that is used in many aerospace applications.